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Classification of Building Object Types

Misconceptions, challenges and opportunities

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Publication date:
2011

Document Version
Early version, also known as pre-print

CLASSIFICATION OF BUILDING OBJECT TYPES – MISCONCEPTIONS, CHALLENGES AND OPPORTUNITIES

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ABSTRACT

Development of the existing classification systems has been very difficult and time consuming tasks, where many considerations have been taken and many compromises have been made. The results reveal that, although the theoretical foundation was clarified, many deviations and shortcuts have been made. This is certainly the case in the Danish development.
Based on the theories about these abstraction mechanisms, the basic principles for classification systems are presented and the observed misconceptions are analyses and explained. Furthermore, it is argued that the purpose of classification systems has changed and that new opportunities should be explored. Some proposals for new applications are presented and carefully aligned with IT opportunities. Especially, the use of building modelling will give new benefits and many of the traditional uses of classification systems will instead be managed by software applications and on the basis of building models.
Classification systems with taxonomies of building object types have many application opportunities but can still be beneficial in data exchange between building construction partners. However, this will be performed by new methods and in strong connection with databases holding a wide range of object types.

Keywords: classification, composition, taxonomy, classification system, building model

1. INTRODUCTION

Many different classification systems have been developed during the last fifty years and the primary purpose has been to support data exchange between partners in building construction projects in traditional document based collaboration processes. However, these processes have changed, new model based design approaches have been developed and, therefore, new demands for classification systems have been raised.

Various classification systems have been developed by different nations and institutions, e.g. SfB, BSAB in Sweden (BSAB 1998), CI/SfB (Ray-Jones 1978), Uniclass in UK (Uniclass 1997), Building 90 in Finland and OmniClass in North America (OmniClass 2006). In Scandinavian, the SfB classification system was introduced already around 1950. In Sweden, further developments took place over many years and the current system is BSAB 96 (BSAB 1998). Similarly, the SfB/UDC was introduced in UK around 1960 and was revised in 1976 as CI/SfB. This system has been succeeded by the Uniclass system in 1997. In Denmark, a rather new proposal Dansk Bygge Klassifikation (DBK) has been published in 2006 to replace the existing SfB system (BIPS 2006). OmniClass and Uniclass are both faceted classification systems, each incorporating 15 tables representing many specific facets of construction information.

The intensive discussions in the Danish building construction industry about development of a new classification system have led to the observations that there are many misconceptions about classification. Many building industry professionals do not distinguish between the process of classifying object individuals and the development of classification systems – the foundations for classifying. A major confusion seems to be that no clear distinction is made between composition and classification, which are regarded as two fundamental abstraction mechanisms.

Any kind of description of a building can be regarded as a *model*, so models play an important role in connection with buildings (Jørgensen 2008). Most often, the backbone in descriptions or building models of individual buildings is the *building structure*, i.e. a *whole-part structure*, where the building is subdivided into components/parts, which again are subdivided into other components/parts etc. down to an appropriate level. This is termed *composition* and such a structure can be formed in many ways depending on the purpose. In different building life phases, the structure and the need for details may be different; so, a suitable description as the basis for construction may not be ideal for the operations and management. In this phase, for instance, detailed description of many basic components like kernels of foundations, walls and slabs may be of minor importance while more detailed descriptions about coverings and building service components may be of greater importance.

General regulations about how descriptions and specifications of buildings should be formed will naturally also include provisions for the structure and the sequence in which description parts should occur. Such regulations or recommendations may be published by certain authorities, associations or organisations and aim at specific categories of buildings. The purpose of creating such regulations should be to standardise building descriptions and thereby to make it easier to share and compare building descriptions between partners.

The Danish DBK regulation is claimed to be a classification system but, seen from a theoretical point of view, it is not. Although it has a general nature and it may be argued that the used terms represent classes of components, the overall characterisation is that DBK is a regulation for describing the whole-part structure of buildings. *Identification of classes is not classification. Classification is something else and more than just that.*

2. FUNDAMENTALS ABOUT CLASSIFICATION

Classification is an *abstraction mechanism* by which component classes can be arranged in a hierarchy, termed *taxonomy* (Jørgensen 1998) (Jørgensen 2004) (Smith 1977a) (Smith 1977b). The most general classes are at the higher levels (root levels) and the most special classes are at the lower levels. This means that, at any node, the sub-classes must be *specialisations* of the super-class and, in contrast, any super-class is a *generalisation* of its sub-classes. Each sub-class is said to *inherit* the attributes of the super-class and, in addition, each sub-class must have its own attributes. Classification is the foundation for the paradigm *object-orientation*, which has a general scope but most extensively has been used in software development (Rumbaugh 1991) (Booch 1998).

Composition, as described above, is also an abstraction mechanism, but clearly the two abstraction mechanisms are very different. Classification and composition are sometimes characterised as *orthogonal* to each other. Classification may be very useful in modelling as the basis for identification and creation of components and, when components are created, the composition structure can be created. In this way, both abstraction mechanisms will be used in modelling tasks.

For a selected set of components, multiple classifications can be developed and it is therefore necessary to select a *classification criterion* to determine the nodes of the taxonomy. Hence, different classification criteria result in different taxonomies of the same components. If each node in the hierarchy can express a class according to only one criterion, the classification is *clean* and if multiple criteria are used, the classification is *mixed*. In this case, only one criterion should be used on each level of the taxonomy. A criterion must be selected due to a purpose, so not all classifications (included clean classifications) may be useful or relevant for a selected purpose.

Ideally, components belong to only one node in a taxonomy, but very often components can be characterised by multiple nodes. In this case, it is often possible to identify one of the nodes as the primary characterisation, i.e. the *primary* class. The other classes are *secondary* classes.

Taxonomies can give overview and make it easier to identify something new in a modelling process. By having classifications in advance, this can support finding and selection among presented alternatives as illustrated in Figure 1. The purpose and practical use of taxonomies for identification of building components may be very different in different life phases of a building. In the very early phases, a primary purpose could be to give inspiration about what functions should be required or provided by the building or by building components.

In building modelling, selection of new building model components is necessary many times. At first, such components may be major model components and only roughly specified, i.e. no internal structure is defined and only few attributes are determined. Later on, the model components are detailed by two dimensions: *specification* and *structure*. Specification detailing concerns further identification of attributes and structure detailing includes sub-division into sub-components, ultimately down to *building products*, *building articles* or *building materials*. Thus, key issues about data exchange in connection with modelling are to formulate requirements about the degree of model detailing and it should be possible to support all levels of detail by taxonomies.

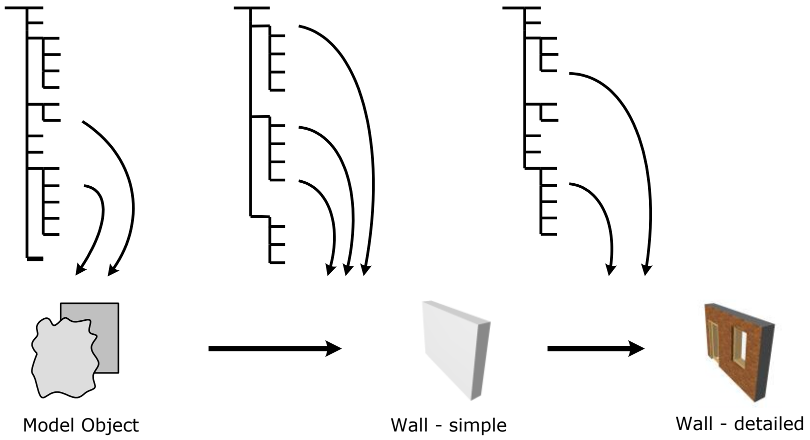

Figure 1: Use of classifications (taxonomies) in modelling and model detailing

3. CHALLENGES REGARDING EXISTING CLASSIFICATION SYSTEMS

Many existing classification systems are referring to the standard ISO 12006-2, Organization of information about construction works – Part 2: Framework for classification of information (ISO 2001). In this standard, the concept *element* is introduced as a foundation for classification. The concept is defined as *"a construction entity part which, in itself or in combination with other such parts, fulfils a predominating function of the construction entity"*. This concept represents an abstraction and underlines that, in the initial life phase of a building model component, only functions are considered and e.g. technical solutions, material possibilities and construction methods are not taken into account.

OmniClass Table 21 Elements (Including Designed Elements) is organized by *elements' implied functions* and Uniclass Table G covers elements of buildings. BSAB 96 deals with the element definition and differs from the ISO standard. It defines a slightly different concept, where the phrase *"in itself or in combination with other such parts"* is omitted (Ekholm 2003) and, consequently, it is explicitly stated that only the *main function* of elements is used as basis for classification. To use function or main function as a classification criterion for building components is questionable. As stated, every building component has many functions and could potentially occur multiple times in a taxonomy. To focus on the main function of each building component limits this problem but the main function of a building component may depend on the actual location in the building and the relationships with other building components. Consequently, a taxonomy of building components structured by use of the function criterion will not provide a unique overview and will be difficult to use.

As previously stated, building components can be decomposed and assembled and this is clearly underlined in OmniClass in relationship with Table 21 and this is also highlighted in connection with BSAB 96. The first steps of modelling often regards major and often composite components but such components create major problems regarding classification by function because they represent multiple functions and, thus, identification of main functions may be difficult. Otherwise, such element classes may occur at multiple positions in classification taxonomies. In BSAB 96, a separate entry is reserved for classification of composite elements and systems as a separate classification compared to elements. Consequently, there are conflicting requirements regarding modelling and classification.

Besides the problem of including composite components in the classification, it is a key question whether the existing classification systems conform to the theory of classification or not. There are some indications that the two abstraction mechanisms classification and composition are mixed up in the tables. In OmniClass Table 21, a few examples show that it is done at lower levels of the tables, probably in order to simplify and to increase the usability, e.g. 'Subgrade Walls (includes: Wall

Supports)'. At an upper level of the table, the divisions of 'Structure' into 1) 'Substructure', 2) 'Superstructure and Enclosure', 3) 'Enclosure', 4) 'Interior' and 5) 'Signage' could easily signify a division by composition (a whole-part structure) but it is important to interpret the division as sub-classes.

4. DEVELOPMENT OF CLASSIFICATION SYSTEMS

A major issue about all the classification systems is that the classification criteria are not clearly stated. In case that functions are the criteria, these are only expressed indirectly, e.g. 'substructure' and 'superstructure' in OmniClass Table 21. Furthermore, there are many examples, where mixed classification is performed, i.e. multiple classification criteria are used. In BSAB 96, the above mentioned separate entry for composite elements is one example. However, this table is formed by levels, where different classification criteria may exist for each level. For instance, several entries are characterised as completion element and this is not a division based on element function. Similarly in OmniClass, there are many examples, where function is not the expressed criterion, e.g. divisions under 'superstructure': 'floor construction', 'conveying systems', 'bridge construction' and 'tower superstructure construction'. Further, the position 'conveying systems' is subdivided into e.g. 'vertical', 'horizontal' and 'sloped' transportation, which is rather a form criterion. Finally, also materials are used as criterion.

Overall, the existing classification systems are primarily oriented towards physical building components, which are identified from a geometrical point of view. New needs in relationship with building modelling are not incorporated. In such processes, other approaches for identification and creation of building model components may play a prominent role.

The issues, which have been discussed above, have created the idea that the subject should be turned upside down. Instead of classifying building components by function, it would be better to classify functions and attach building component types/classes to function nodes. Referring to Figure 1, the idea is that the first taxonomy to be used in a modelling approach should be a *taxonomy of functions* (Jørgensen 2009).

When building components have already been identified by functions, a subsequent modelling phase will include tasks, where each model component needs to be further specified and detailed and e.g. the building component type and subsequently a specific technical solution must be determined. In this process, a taxonomy of building components may be useful for selection of alternatives.

In general, it is important that the construction partners can exchange information about building components and various taxonomies of building components may support this as illustrated in Figure 1. According to ISO 12006-2, classifications of *designed elements*, *work results* and *products* would be useful. It may be useful to have multiple classifications of building components but it would of cause be simpler, if one superior taxonomy could satisfy the needs for detailing. As stated, a taxonomy of building components will be necessary but a taxonomy of products will also be useful and producers of such products can, with reference to this taxonomy, publish information about the products. This would enable designers, constructors and other consumers to use the taxonomy to find alternative products. Examples of such useful information are detailed product description, instructions for handling and assembly of components, instructions for maintenance, warranties, prices and cost values.

As stated, a taxonomy of building components can be used as the underlying structure for sharing and exchange of data about components of the class. This means that data of different kind can be attached to each node and used in subsequent detailing work. A special issue is then about how to relate this taxonomy to IFC classes. All relevant IFC classes (sub-classes of IfcProduct) will occur in the hierarchy and, consequently, modelling tools can be based directly on IFC.

It is important to state that relationships can be established between taxonomies (illustrated in Figure 2). When a model object is initially created by selecting a main function, a component type can be selected via the relationships, i.e. a set of component types can provide the function. For e.g. the function 'elevate/lower' as a sub-function of 'passing (to/from/between)', related sample component types could be staircases, lifts/elevators or escalators and, similarly, for the function 'heating production', e.g. boilers could be referenced.

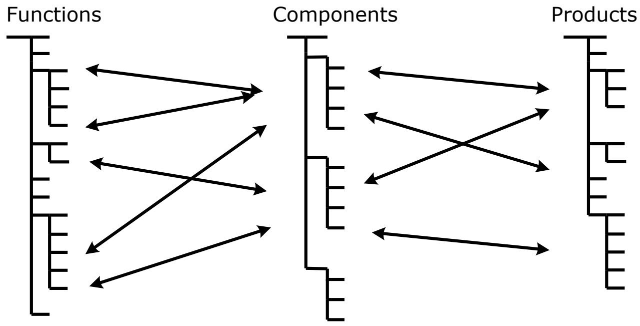

Figure 2: Relationships between taxonomies support efficient specification and detailing processes

The reverse relationships are also very useful. They will show, which functions are considerable for specific component types. Consequently, if a component type were selected in the component taxonomy, relationships to functions would indicate, which secondary functions could be selected. This would be important in order to add attributes to each component for further specification.

Similarly, very useful relationships between the component taxonomy and the product taxonomy could be established. Each component type could refer to a set of products, which could replace the component.

5. THE DANISH PROPOSAL DBK

In contradiction to existing classification systems, the building components table of the new Danish DBK system is not a classification system but instead the division is made as a whole-part structure. This has recently been concluded in an evaluation report (Ekholm 2011). The top division of the table is by systems: 'Site system', 'Foundation system', 'Wall system', 'Slab system', 'Roof system', 'Water system', etc. and for example the 'Wall system' can consist of 'window panel', which again consists of 'window', etc. Functions of components are listed in a separate sub-table.

The primary proposal is the introduction of what is termed as *reference designations*, adopted from the ISO/IEC 81346 standard, which has been used to describe equipment in industrial systems. The use of this methodology is claimed to be about *identification* of objects of interest by applying reference designations for three views or aspects: the *product aspect*, the *location aspect* and the *function aspect*. The use of reference designations is not new, referencing is not about identification but instead about specification, and the proposal does not address a modern design process working with building models.

The primary purpose of using reference designations should be to enable users to add further data to a description of an object, most likely a model object. According to the proposal, the reference designation '-205.02.01' refers to the entry in the underlying table for the product aspect: 'wall system – window panel – window'. Similarly, '=20.01' refers to the entry in the underlying function table: 'illuminate with daylight'.

This way of adding data to an object is not at all new. It is a way of making *specification* and for instance in the theory of relational databases, it is well known in the last nearly 40 years as the concept *foreign key attributes*. Furthermore, it is comprehensively implemented as *relationships* in *Industry Foundation Classes* (IFC).

The proposal gives the wrong impression about reference designations by claiming that referencing is about *identification*. The traditional understanding is that, when a model object is created, it has a set of attributes to which values can be assigned. One of these attributes is the *identifier* of the object and the value is either user defined or most often system defined (automatically generated) and is supposed to be left unchanged for the rest of the object's life time. Obviously, the object identifier can be used whenever it is necessary to refer to the object from other objects. In for instance IFC, the Global Unique Identifier (GUID) is system generated and can be used in relationships.

Other misleading statements are about *identifying attributes* in the context of searching for one or more objects, presumably without knowing the identifier. This is also termed *querying*, where the search is guided by *query conditions*.

As mentioned, the DBK proposal introduces the use of *aspects*. This is also not at all new in connection with specification. It is just a way to characterize specifications, e.g. of attributes or properties and has been know all the way back to Aristoteles.

For the product aspect, a table is developed and, as indicated above, entries of this table are supposed to be used for specification of (model) objects. This table is a generic description of "whole-part" structures of buildings and a *function table* is developed as an extension. It is claimed that this foundation is better than classification.

It must be added that, if the product aspect table should be complete, it will be an enormous large table and, even worse, it will contain many duplicates. Consequently, the table will be impossible to overview and difficult to maintain. The use of the function table is also limited because it is linked to the composition table and it is thereby assumed that the composition is defined first. This is definitely not always the case in design processes. Often, considerations about functions come first.

The location aspect has no underlying table but is the definition of a rule for description of location. For example, the reference designation '+1.002' refers to "storey 1 room 002".

The most important evaluation, however, is that specification according to the product aspect and the location aspect is completely needless, at least when it comes to working with building models. As it is well known, the wide range of possible relationships between objects in a building model represented in IFC give many possibilities for extracting and presentation. Furthermore, it is possible to add many kinds of properties via IFC *Property Sets*.

Regarding the product aspect, there are even two kinds of *decomposition* relationships: *aggregation* of objects of different types and *nesting* of objects of the same type. In addition, the relationship *"contains in spatial structure"* makes it possible to link space objects with building construction components and vice versa. If this is not enough, other kinds of data can be included by referencing via the association relationship.

Regarding specification according to the location aspect is also needless because each object has exact *coordinates* for the definition of the location. Even global spherical coordinates can be specified if required.

The statements above give firm arguments that the DBK proposal is seriously misleading regarding terminology and is needless or unsuitable for modern work processes with building models. The following section will further illustrate the stated arguments.

6. MODEL OBJECTS AND RELATIONSHIPS

When building models are created, specific building components are selected and related to each other. The individual building components can be seen as *instances* of the component classes, which are included in the taxonomy above. For each component, a type is selected, the component is created and values are assigned to the attributes of the component.

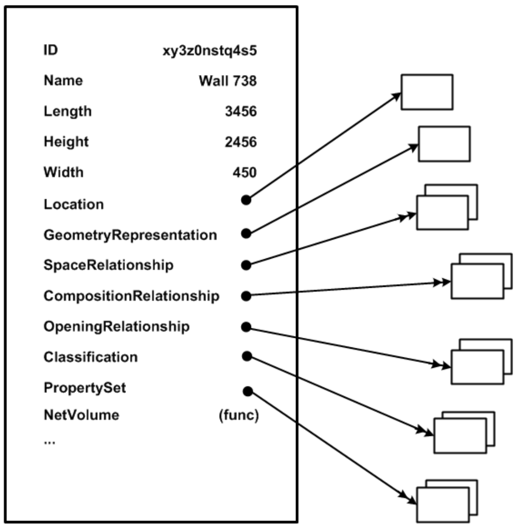

Figure 3: Model object of a wall with different kinds of attributes.

Besides the ordinary model object attributes, which can carry numeric values, text values, logical values, etc., attributes can also be used to represent relationships between objects. The most simple relationship attribute is the *reference attribute*, which can be assigned a link to another object, a one-to-one relationship. Another relationship type is the *collection*, which in short is a one-to-many relationship[1]. This relationship can also be represented by an attribute, hence a *collection attribute*. An example of the use of these kinds of attributes is shown in Figure 3. Reference attributes are represented by single headed arrows and collection attributes are represented by double headed arrows. As a special form of the reference attribute, it can refer to external data, for instance via data base entrances or web addresses.

As already stated, numeric attributes for one or more functions can be attached when functions are selected from the function taxonomy and other attributes can be provided, when the component type is selected from the component type taxonomy. If further relevant data are attached to building component types in the hierarchy and proper attributes are available, these data may be transferred directly to the model objects. Other sorts of data may be linked to the model components through relationship attributes with external references.

In order to support an efficient modelling approach, modelling tools must have the taxonomies implemented. They must also have tool specific libraries, which may be further detailed in order to provide a wide range of solutions.

7. COMPOSITION OF BUILDING COMPONENTS

As previously stated, modelling tools create *model objects* and *relationships between the model objects*. If an IFC representation is generated, an overall spatial structure must be included: Project – Site – Building – Storey etc. To this structure, spaces and construction components can be related. A rather simplified illustration of this is shown in Figure 4 based on a small building model example. Based on these relationships, different *access paths* are available for navigation to the components and typically these access paths can be used to organise different composition hierarchies.

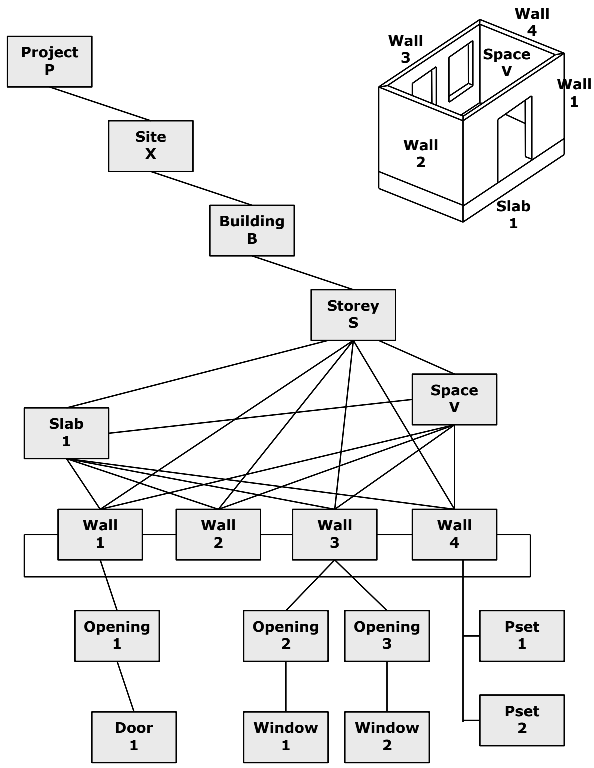

Figure 4: IFC representation of building model (simplified example)

1 For the sake of simplicity, only these two types of relationships are stated.

The individual construction components are instances of the component types taxonomy and structures of construction components can be extracted and organised in many ways based on the relationships illustrated in Figure 4. Often, the primary structure is based on the storeys of the building as shown in the following example Hierarchy 1, which is typical for IFC based applications. The composition structure then starts with the instance of the building class and the next level includes instances of the storey type. The subsequent levels comprise instances of building components. Observe that component types from classification systems can be used for nodes in order to clarify the content on the next level, see for instance the node 'Walls'.

Hierarchy 1 – Sample composition hierarchy of building construction components

```
Building
.   Basement
.   .   ....
.   Ground floor
.   .   Walls
.   .   .   Wall 1
.   .   .   ....
.   .   .   Wall 2
.   .   .   .   Window 1
.   .   .   .   Window 2
.   .   .   .   Door 1
.   .   .   .   .   Door frame
.   .   .   .   .   ....
.   .   .   .   ....
.   .   .   .   Wall layers
.   .   .   .   .   Layer 1
.   .   .   .   .   Layer 2
.   .   .   .   ....
.   .   .   ....
.   .   Floor slabs
.   .   .   Floor slab 1
.   .   .   .   Hatch 1
.   .   .   ....
.   .   Columns
.   .   ....
.   .   Beams
.   .   ....
.   First floor
.   ....
```

The Danish DBK system (BIPS 2006) proposes another composition hierarchy, where buildings at the top level are divided into systems, see Hierarchy 2.

Such composition structures can form the basis for various kinds of descriptions of a building or a building model, for instance quantities, cost calculations, activities and work instructions. The higher levels of the hierarchy can represent aggregated data, e.g. the sum of cost.

Many other structures can be formed depending on the relationships between building components. If for instance, relationships are created between rooms and the construction components, which demarcate the rooms, such a structure could also be generated. Further, when operations and maintenance have to be planned, the focus is often different. For instance, the primary building components have minor importance whereas windows, doors, dormers, bay windows, roofs, surfaces, etc. are much more important.

It may be useful to form regulations, which standardise building descriptions and thereby make it easier to share and compare building descriptions between partners. However, it is not necessary to do it by creating a complete table like the attempt made in the Danish DBK.

Hierarchy 2 – DBK composition hierarchy of building construction components

Building
. Site system
. . ....
. Foundation system
. . ....
. Wall system
. . Wall construction
. . . .
. . Window panel
. . . Window
. . . . Frame
. . . . Pane
. . . .
. . . Panel
. . . .
. . . Connection
. . . .
. . Door panel
. . ....
. Slab system
. . ....
. Roof system
. . ....
. Water system
. . ....
. Drainage system
. . ....
. Gas and air system
. . ....
. Cooling system
. . ....
. Heating system
. . ....
. ....

8. CONCLUSION

Classification is an abstraction mechanism and this theory is the basis for development of classification systems. A selection of existing classification systems is presented and some misconceptions are observed, analysed and explained. Especially, a new proposal for the Danish building industry is presented. Many misleading recommendations are analysed and it is argued that the proposal is not a classification system and does not add new developments to increase the productivity.

It is argued that the purpose of classification systems has changed and that new opportunities should be explored. Based on common IT opportunities, some proposals for new applications are presented and, especially, because the use of building modelling will give new benefits, many of the traditional uses of classification systems will instead be managed by software applications based on building models.

Classification systems with taxonomies of building object types have many application opportunities but can still be beneficial in data exchange between building construction partners. However, this will be performed by new methods, which also support specification of model attributes.

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